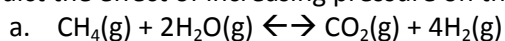
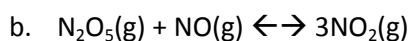


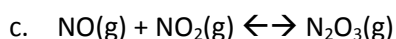
1. Predict the effect of increasing pressure on the position of equilibrium in the following systems:



3                      5                      shift to left



2                      3                      shift to left



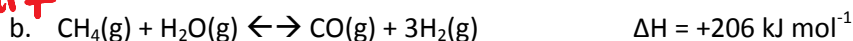
2                      1                      shift to right

2. Predict the effect of increasing temperature on the position of equilibrium in the following systems:



shift to left

heat +



shift to right



shift to left

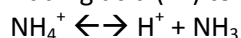
3. Predict the effect of the following changes on the position of equilibrium:

a. Removing the  $\text{CO}_2$  from the equilibrium:



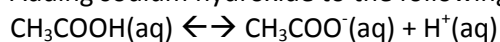
shift to right

b. Adding acid ( $\text{H}^+$ ) to the system:



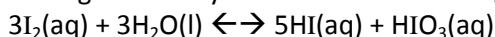
shift to left

c. Adding sodium hydroxide to the following system:



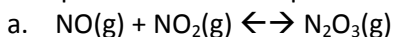
shift to right

- d. Adding sodium hydroxide to the following system:

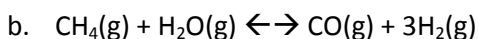


shift to right (NaOH will react w/ HI)

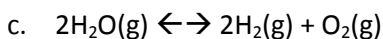
4. Write expressions for the equilibrium constant for the following reactions:



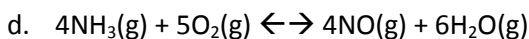
$$K_c = \frac{[\text{N}_2\text{O}_3]}{[\text{NO}][\text{NO}_2]}$$



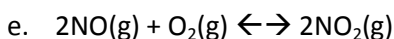
$$K_c = \frac{[\text{CO}][\text{H}_2]^3}{[\text{CH}_4][\text{H}_2\text{O}]}$$



$$K_c = \frac{[\text{H}_2]^2[\text{O}_2]}{[\text{H}_2\text{O}]^2}$$

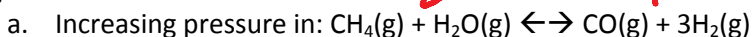


$$K_c = \frac{[\text{NO}]^4[\text{H}_2\text{O}]^6}{[\text{NH}_3]^4[\text{O}_2]^5}$$



$$K_c = \frac{[\text{NO}_2]^2}{[\text{NO}]^2[\text{O}_2]}$$

5. Explain the effect of the stated changes in conditions on the position of equilibrium and the value of the equilibrium constant. In each case state whether the value of the equilibrium constant increases, decreases, or stays the same.



$$\Delta H = +206 \text{ kJ mol}^{-1}$$

shift to left, no effect on  $K_c$



$$\Delta H = +206 \text{ kJ mol}^{-1}$$

shift to right,  $K_c$  increases

- c. Decreasing temperature in:  $\text{H}_2\text{O}(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{CO}_2(\text{g})$  <sup>heat</sup>  
 $\Delta H = -40 \text{ kJ mol}^{-1}$

shift to right,  $K_c$  increases

- d. Increasing concentration of  $\text{H}_2$  in:  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$   
 $\Delta H = -92 \text{ kJ mol}^{-1}$

shift to right,  $K_c$  no change

- e. Increasing pressure in:  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$   
 $\Delta H = -92 \text{ kJ mol}^{-1}$

shift to right,  $K_c$  no change

- f. Introducing a catalyst into the reaction:  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$   
 $\Delta H = -197 \text{ kJ mol}^{-1}$

no shift, no change in  $K_c$

6. Hydrogen for the Haber process can be produced by the reaction between methane and steam:  $\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g})$  <sup>4</sup>  $\Delta H = +206 \text{ kJ mol}^{-1}$  <sup>heat + 2</sup>  
State whether each of the following changes in conditions would: (i) increase, decrease, or have no effect on the yield of hydrogen; and (ii) increase, decrease, or not change the rate of the reaction.

- a. Increasing the pressure

decrease the  $\text{H}_2$  yield, increase rate

- b. Increasing the temperature

increase the yield  $\text{H}_2$ , increase the rate

- c. Introducing a catalyst

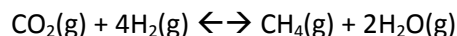
no change on yield, increase the rate

## OLD IB EXAM PROBLEMS

7. Which of the following is a property of a system at equilibrium?

- a. The concentrations of reactants and products are equal.
- b. The rate of the forward reaction is zero.
- c. The rate of the forward reaction is equal to the rate of the reverse reaction.**
- d. The rate of the reverse reaction is a maximum.

8. Consider the reaction:



What is the expression for the equilibrium constant?

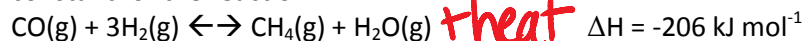
- a.  $K_c = [\text{CO}_2][\text{H}_2] / [\text{CH}_4][\text{H}_2\text{O}]$
- b.  $K_c = [\text{CH}_4][\text{H}_2\text{O}]^2 / [\text{CO}_2][\text{H}_2]^4$**
- c.  $K_c = [\text{CH}_4][2\text{H}_2\text{O}] / [\text{CO}_2][4\text{H}_2]$
- d.  $K_c = [\text{CH}_4] + [\text{H}_2\text{O}]^2 / [\text{CO}_2] + [\text{H}_2]^4$

9. In which system will decreasing the pressure increase the equilibrium concentration of the species in bold?

- a.  $\text{CH}_4(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + 4\text{H}_2(\text{g})$**
- b.  $\text{N}_2\text{O}_5(\text{g}) + \text{NO}(\text{g}) \rightleftharpoons 3\text{NO}_2(\text{g})$
- c.  $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$
- d.  $\text{NO}(\text{g}) + \text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_3(\text{g})$

$\downarrow P$  to more gas moles

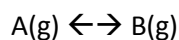
10. What is the effect of increasing the temperature on the position of equilibrium and the value of the equilibrium constant for the reaction:



Position of equilibrium Value of K

- a. Shifts to left Decreases**
- b. Shifts to right Decreases
- c. Shifts to right Increases
- d. Shifts to left Increases

11. Consider the system:



What is the effect of introducing a catalyst?

- a. The rate of the forward reaction increases but the rate of the reverse reaction remains the same.
- b. The position of equilibrium is shifted to the right.
- c. The time taken to reach equilibrium is decreased.**
- d. The value of the equilibrium constant is reduced.

12. Which of the following changes will increase the equilibrium yield of ammonia according to the following equation?



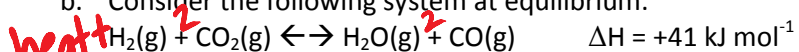
- a. Decreasing the temperature from 200°C to 100°C  
 b. Introducing a catalyst  
 c. Decreasing the pressure from 200 atm to 100 atm  
 d. Increasing the temperature from 100°C to 200°C

13.

- a. Explain what is meant by dynamic equilibrium.

Conc. of react. + products remain constant & rate of forward = rate of reverse

- b. Consider the following system at equilibrium:



State and explain the effect of the following changes on the position of equilibrium and the value of the equilibrium constant.

- i. Increasing the temperature at constant pressure.

• Shifts equl to right as adding heat favors endo thermic reaction

•  $K_c$  will increase since the conc. of prod is increas.

- ii. Increasing the pressure at constant temperature.

• Eq. position doesn't change since mols gas are equal

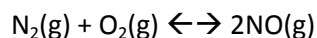
• no change in  $K_c$

- iii. Introducing a catalyst at constant temperature and pressure.

• Eq. position doesn't change, a catalyst just gets it there faster

• no change in  $K_c$

14. Consider the reaction:



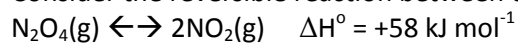
- a. Write an expression for the equilibrium constant for this reaction.

$$K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]}$$

- b. The value of the equilibrium constant for this reaction at 700 K is  $5 \times 10^{-13}$ , but the value at 1100 K is  $4 \times 10^{-8}$ . Use these values to state and explain whether this reaction is exothermic or endothermic in the forward direction as written.

K increased as heat was added so  
reaction is endothermic

15. Consider the reversible reaction between colourless  $\text{N}_2\text{O}_4$  and brown  $\text{NO}_2$ :



- a. Write an expression for the equilibrium constant for this reaction.

$$K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]}$$

- b. State and explain how the colour of the mixture will change as the temperature is increased.

If heat was added to an endothermic reaction the forward direction is favored so the solution would become brown

- c. State and explain the effect of increasing the pressure on the colour of the equilibrium mixture and the value of the equilibrium constant.

Increasing P ( $\downarrow V$ ) would favor the formation of reactants (fewer moles of gas) so the mixture would become colorless. The  $K_c$  wouldn't change because only a change in temp. would change the equil. constant